

Push out bond strength of fiber post to radicular dentin using Q-mix, lemon/garlic extract, and riboflavin activated by photodynamic therapy as a final canal irrigant

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Abstract. – OBJECTIVE: The aim of this study was to assess the extrusion bond values of fiber post to radicular dentin when disinfected using different final irrigants lemon garlic extract (LGE), riboflavin (RFP) activated by PDT (photodynamic therapy), and Q-mix 2-in-1.

MATERIALS AND METHODS: Forty single-rooted mandibular premolar teeth were decoronated. Endodontic treatment was performed, and the canals were continually irrigated with normal saline, dried with paper points, and obturated. Post space was prepared by removing gutta-percha using peso-reamers. All specimens were randomly allocated into four groups based on the final irrigant used. Specimens in Group 1 irrigated with: 5.25% NaOCl+17% EDTA, group 2: 5.25% NaOCl+Q-mix 2-in-1, group 3: 5.25% NaOCl+RFP, and group 4: 5.25% NaOCl+LGE. Following final irrigation, a fiber post was placed in the canal space and luted. Samples were sectioned and each section was placed in a universal testing machine to assess bond values. Debonded samples were assessed for failure modes, EBS and modes of failure. For comparisons among groups, the one-way analysis of variance (ANOVA) test and the Post-Hoc Tukey HSD test were used keeping the level of significance at $p=0.05$

RESULTS: The cervical section of samples in group 2 (NaOCl+Qmix) (7.11 ± 0.81 MPa) exhibited the maximum value of EBS. However, the apical section of samples in group 3 (5.25% NaOCl+RFP) (3.33 ± 0.26 MPa) displayed minimum extrusion bond values. Group 3 specimens in which final irrigation was performed with RFP established significantly lower bond integrity values than all the other investigated groups coronal (3.77 ± 0.13 MPa), middle (3.60 ± 0.41 MPa), and apical (3.33 ± 0.26 MPa) ($p<0.05$). Intragroup compar-

ison analysis, the coronal and middle root sections of all the experimental groups displayed comparable outcomes of EBS ($p>0.05$). However, near the apical section of the root, the bond strength of all the groups declined considerably.

CONCLUSIONS: Q-mix 2-in-1 as the final irrigant displayed the highest extrusion bond strength of fiber-reinforced composite to canal dentin at all three levels coronal, middle and apical. Lemon garlic extract has the potential to be used alternative to ethylene diamine tetra acetic acid as a final irrigant.

Key Words:

Extrusion bond strength, Final irrigant, Lemon garlic extract, Q-mix 2-in-1, Riboflavin photosensitizer.

Introduction

The purpose of root canal therapy is to get rid of bacteria and stop re-contamination. It is impossible to completely clean the canal using instruments alone due to the complicated anatomy¹. Root canal irrigation is considered a crucial adjunct to mechanical instrumentation because it clears the smear layer². Apart from chemomechanical cleansing, sometimes endodontic-treated tooth has a poor prognosis due to excessive structure loss. To minimize the risk of fracture, fiber-reinforced composite post (FRCP) is placed in canal space³. FRCP has a modulus of elasticity to dentin, better aesthetics, stiffness, and fatigue⁴. A gold standard root canal disinfectant is

sodium hypochlorite (NaOCl). Its disinfection mechanism relies on chlorination, neutralization of amino acids, and saponification⁵. However, the available evidence supports that it slightly affects the inorganic portion of the smear layer^{6,7}. Hence, chelating agents have been developed to address this weakness. Ethylenediaminetetraacetic acid (EDTA) is one of many chelating agents that is widely used in dentistry. It interacts with the calcium ions in dentin to create soluble calcium chelates. However, it does not disregard the organic components of the smear layer^{8,9}.

Q-Mix 2-in-1 a ready-to-use irrigant for the elimination of smear layer with antimicrobial effectiveness is introduced. It consists of deionized water, EDTA, CHX, and a detergent and is intended to replace the 17% EDTA as the final wash regimen¹⁰. Q-Mix 2-in-1 solution increases the radicular dentin demineralization due to the chelating effects of EDTA. A recent study by El-naghy et al¹² and Eliot et al¹¹ revealed that Q-Mix 2-in-1 eliminates the smear layer more successfully than 17% EDTA. Apart from Q-Mix 2-in-1 as a final irrigant photodynamic treatment (PDT) has arisen for canal disinfection. Riboflavin photosensitizer (RFP) is one such photosensitizer that can be photoactivated to release free radicals¹³. In recent work by Altaf et al¹⁴ riboflavin (RFP) improved the EBS of FRCP to dentin.

Natural and organic therapies are a source of inspiration for medical and dental clinicians these days. The use of natural extracts as a therapeutic is known as “phytotherapy” or “ethnopharmacology”. In a study by Siddique et al¹⁵ lemon/garlic extract (LGE) was used as a canal irrigant and displayed better antimicrobial efficacy than NaOCl. According to the study by Ajay Rao et al¹⁶ garlic displays substantial tissue-dissolving capability. However, its pungent smell limits its use in dentistry. Constructed on the previously available scientific literature, it can be anticipated that the combination of LGE, when used as a final irrigant, may offer benefits of both disinfection and smear layer removal, along with anti-inflammatory, antifungal, antiviral, and antioxidant properties¹⁶. Therefore, it was hypothesized that canal disinfection with final irrigant (LGE, RFP activated by PDT and Q-mix 2-in-1) will show no difference in EBS of fiber post bonded to the canal wall compared to conventional final irrigant EDTA. The present study aimed to assess the extrusion bond values of fiber post to radicular dentin when disinfected using different final irrigants LGE, RFP activated by PDT, and Q-mix 2-in-1.

Materials and Methods

The *in vitro* study included 40 single-rooted mandibular premolar teeth with fully developed apices that had been extracted for orthodontic purposes. A 0.9% thymol solution was used to store the specimens which had only one canal, non-carious with no fracture. Samples with cracks, dilaceration, and calcification were excluded. All samples were scaled off using a periodontal curette and submerged in 10% formalin solution for 7 days followed by storing them in normal saline at a temperature of 37°C till the time of future use. The present *in vitro* study followed a checklist for reporting *in vitro* studies (CRIS) guidelines and was approved by the institutional review board #COD/IRB/2021/91¹⁷.

Preparation and Root Canal Treatment of the Teeth

To achieve a standardized root length of 15 mm, the decoration was carried out under continuous irrigation of water using a sterilized low-speed diamond saw (IsoMet 5000; Buehler, Leeds, UK). All samples underwent endodontic treatment using the NiTi ProTaper universal system till the F3 finishing file. Between and after root canal cleaning and shaping, the canals were continually irrigated using normal saline. The canal was dried using paper point (Pt Dent, USA) and gutta-percha (Dentsply Maillefer, Ballaigues, Switzerland) was used for obturation with a AH Plus sealer (Dentsply, Caulk, Milford, Germany) using lateral condensation technique. After 72 hours gutta-percha was removed using peso-reamers sequentially #2, #3, and #4, and post space was prepared. The canal space of all specimens was sterilized with 5.25% NaOCl. All the specimens were randomly allocated into 4 groups based on the final irrigant used (n=10)¹⁸.

Group 1: 5.25% NaOCl+17% EDTA (Control)

In this group, a 30-gauge needle was used to wash the canal space with 5 mL of 17% EDTA as a final irrigant for 60 seconds.

Group 2: 5.25% NaOCl+Q-mix 2-in-1

In this group, the anal space was irrigated with 5 mL Q-mix 2-in-1 solution (Dentsply Tulsa Dental, Tulsa, OK, USA) as a final canal irrigant for 60 seconds.

Group 3: 5.25% NaOCl+RFP

Canals in this group were brushed with 150 g/ml RFP activated using a 660 nm LED light with

150 mW power for around 60 seconds. The fiber optic tip of the LED was seeded in the canal parallel to the long axis¹⁹.

Group 4: 5.25% NaOCl+LGE

LGE was used as the final irrigant. After being dried, fresh garlic was grounded in an electronic miller. In a Soxhlet extraction device, 60 g of garlic was put in a tared extraction thimble and extracted with 95% ethanol for roughly 3 hours. The ultimate concentration was determined to be 1.8% and was made by adding an equal volume of freshly made sterile lemon juice. Using a 5 ml 30-gauge needle the extract was injected in the post space for 60 sec¹⁵.

Following the final irrigation, all samples were dried using paper points. In each post space, FRCP was placed cleaning the fiber post with 70% ethanol. The post was luted to the canal wall using self-cure resin cement Panavia F 2.0 (Kuraray Dental, Tokyo, Japan) and cured using LED light (Elipar S10, 3M ESPE, Neuss, Germany). All samples were placed at a temperature of 37°C and relative humidity of 100% for around seven days. All the specimens were rooted in transparent acrylic resin present in a polyvinyl pipe. Root sectioning was carried out to attain slices of 1 mm thickness. Sectioning begins from 1 mm from the root apical area until the cemento-enamel junction with the help of a diamond blade disc placed in an Isomet machine (Isomet, Buehler, Lake Bluff, IL, USA) placing it perpendicular to the vertical axis of the root maintaining a continuous supply of water²⁰.

EBS and Failure Analysis

Using a universal testing machine (BIET, Davangere, India), compressive loads were then applied to the resulting slices with the aid of stainless steel cylindrical plungers having varied

diameters i.e., coronal third: 1 mm, middle third: 0.8 mm, and apical thirds: and 0.3 mm. The load was delivered at a crosshead speed of 1 mm/min until the post was displaced. Megapascals (MPa) were used to measure the amount of force needed to break the post-bond with the radicular dentin. Under a stereomicroscope (Olympus SZ61, Olympus Optical Co., Tokyo, Japan) at a 40X magnification, the debonded samples were examined to determine the failure mode.

Statistical Analysis

A statistical program for social science SPSS Statistics 21.0 (IBM Corp., Armonk, NY, USA) was used to analyze EBS and modes of failure. For comparisons among groups, the one-way analysis of variance (ANOVA) test and the Post Hoc Tukey HSD test was used keeping the level of significance at $p=0.05$.

Results

Table I and Figure 1 represents the EBS results of the experimental groups at the coronal, middle, and apical thirds. It was observed that the cervical section of samples in group 2 (NaOCl+Q-mix) (7.11±0.81 MPa) exhibited the maximum value of EBS. However, the apical section of samples in group 3 (5.25% NaOCl+RFP) (3.33±0.26 MPa) displayed minimum extrusion bond values.

Results related to intergroup comparison analysis disclosed that all the three root sections i.e., coronal (5.85±0.16 MPa), middle (5.45±0.12 MPa), and apical (4.21±0.71 MPa) of group 1 specimens (NaOCl+17% EDTA) demonstrated no significant difference in EBS values compared to group 4 specimens (5.25% NaOCl+LGE), coronal (5.71±0.25 MPa), middle (5.31±0.15 MPa), and apical (4.20±0.84 MPa) ($p>0.05$). In contrast, group 3

Table I. Means and Standard deviations (SD) of extrusion bond strength (MPa) values among experimental groups at the cervical, middle, and apical levels of root.

Groups	Cervical	Middle	Apical
Group 1: 5.25% NaOCl+17% EDTA (Control)	5.85±0.16 ^{a,A}	5.45±0.12 ^{a,A}	4.21±0.71 ^{a,A}
Group 2: 5.25% NaOCl+Qmix	7.11±0.81 ^{b,A}	7.04±0.21 ^{b,A}	6.61±0.32 ^{b,A}
Group 3: 5.25% NaOCl+ RFP	3.77±0.13 ^{c,A}	3.60±0.41 ^{c,A}	3.33±0.26 ^{c,A}
Group 4: 5.25% NaOCl + LGE	5.71±0.25 ^{a,A}	5.31±0.15 ^{a,A}	4.20±0.84 ^{a,A}

Sodium hypochlorite (NaOCl); Ethylene diamine tetraacetic acid (EDTA); Riboflavin Photosensitizer (RFP), Lemon garlic extract (LGE). Different superscript lower-case alphabets denote statistically significant differences within the same column ($p<0.05$). Data with different upper-case alphabets denote significant differences within each row ($p<0.05$).

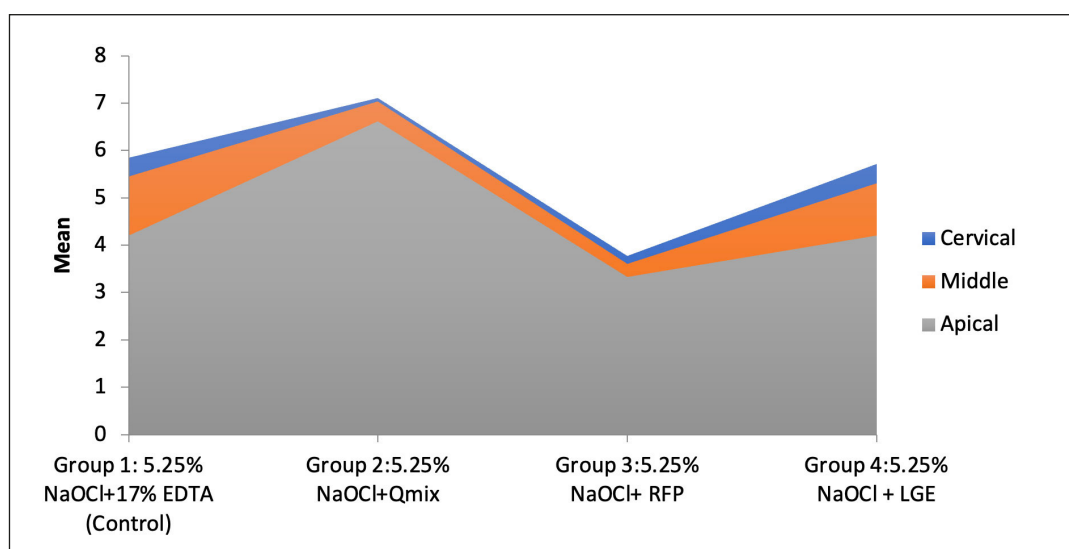


Figure 1. Extrusion bond strength of fiber post to radicular dentin in different experimental groups.

specimens in which final irrigation was performed with RFP established significantly lower bond integrity values than all the other investigated coronal (3.77 ± 0.13 MPa), middle (3.60 ± 0.41 MPa), and apical (3.33 ± 0.26 MPa) groups ($p < 0.05$). According to intragroup comparison analysis, the coronal and middle root sections of all the experimental groups displayed comparable outcomes of EBS. ($p > 0.05$). However, near the apical section of the root, the bond strength of all the groups declined considerably. Figure 2 demonstrated the percentage of failure type for each tested group. Adhesive failure was shown to be the most prevalent failure mode across all groups, followed by cohesive and admixed failure patterns.

Discussion

The present study was constructed on the hypothesis that canal disinfection with final irrigant (LGE, RFP activated by PDT and Q-mix 2-in-1) will show no difference in EBS of fiber post-bonded to the canal wall compared to conventional final irrigant EDTA. The assumed hypothesis was partially accepted as canal space disinfected by 5.25% NaOCl+Q-mix 2-in-1 before bonding of fiber post displayed comparable bond integrity to that of post space irrigated with 5.25% NaOCl+17% EDTA.

To our astonishment, 5.25% NaOCl+Q-mix 2-in-1 displayed significantly better outcomes of bond scores to control. The push-out test is fre-

quently used to evaluate fiber post-adhesion to the canal wall. It is also regarded as a useful instrument for assessing the bond strength values attained by various root canal sealers^{21,22}. EBS using UTM distributes shear stress at the post/cement and dentin cement interface. The method of evaluating EBS is reliable, convenient, and universally acceptable giving comparable outcomes against multiple groups²³. The Q-mix 2-in-1 solution being a combination of EDTA, CHX, a detergent, and deionized water not just removes the smear layer but it penetrates the dentinal tubules promoting antibacterial properties¹¹. The results of the existing study revealed that Q-mix 2-in-1, when used as the final irrigant at all three root levels demonstrated, the highest bond integrity values. The highest EBS attained by this group of specimens can be explained based on the findings of the previous studies^{24,25}. Various evidence suggests that Q-mix 2-in-1 removes the smear layer as efficiently as 17% EDTA solution^{26,27}. Better removal of the smear layer from the root dentin surface leads to better penetration of cement into the dentinal tubules resulting in enhanced bond strength.

LGE as the final irrigant displayed comparable findings of EBS of fiber post to that of conventional irrigant EDTA as the final irrigant. Garlic possesses the ability to eliminate the inorganic part of the smear layer and also displays acceptable antimicrobial properties with negligible side effects²⁸. A study by Ajay Rao et al¹⁶ revealed that a higher concentration of garlic extract was

equally efficient in removing the smear layer in comparison to EDTA. Likewise, lemon juice consisted of components like ascorbic acid, phenolic acids, polyphenols, and dietary fibers which enhance the smear removal capacity^{29,30}. Moreover, lemon in LGE masks the pungent smell of garlic by inhibiting the production of volatile sulfide compounds³¹. This combination can become a potential final irrigant in endodontics.

RFP when used as the final irrigant in post-space-treated specimens displayed the lowest values of EBS. Data from earlier investigations have demonstrated that ROS generated during the photoactivation of RFP disrupts adhesive resin cement's polymerization chain reaction and also creates an O₂ inhibitory layer on the radicular dentin surface^{13,32}. This layer, therefore, makes it difficult for adhesive cement to adhere and penetrate within the dentinal tubules thus weakening the bond.³³ According to failure mode types, it can be stated that in all the experimental groups' adhesive failure was dominant. The findings of previous literature are consistent with the prevalence of adhesive failures at the cement-dentin interface, which can be explained by the fact that moisture in post space; high C-factor, and variations in dentinal tubules favor adhesive failure^{21,23}.

Limitations

There are certain inherent limitations in the current study. The *in vitro* design of the study reduces the generalizability of the findings. Variations in radicular dentinal structure and anatomy of dentinal tubule between each sample may have influenced the results. Moreover, topographic analysis along with dispersive spectroscopy of radicular dentin may provide a better outlook on the influence of the final irrigant on post space.

Conclusions

Q-mix 2-in-1 as the final irrigant displayed the highest extrusion bond strength of fiber-reinforced composite to canal dentin at all three levels coronal, middle and apical. Lemon garlic extract has the potential to be used as an alternative to ethylene diamine tetra acetic acid as a final irrigant.

Authors' Contributions

ASA, BA, AAB: data collection, study design, manuscript writing, final manuscript approval.

ASA, HA, AAB: data collection, study design, manuscript drafting, data analysis, manuscript approval.

BA, NA, KK: data collection, manuscript approval, and data interpretation.

NA, HA, KK: data collection, writing, revision, editing, and final manuscript approval.

FEG, AAA: manuscript revision, writing, and data collection.

All authors are responsible and accountable for the accuracy and integrity of the work.

Acknowledgements

The project was supported by the Deanship of Graduate Studies and Scientific Research at Dar Al Uloom University, Riyadh, KSA.

Conflict of Interests

The authors declared no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

Ethics Approval

This study was approved by the institutional review board (#COD/IRB/2021/91).

Informed Consent

Not applicable.

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